**SWQM Advisory Group Handout for September 21, 2004 Meeting**

The following discussion of sediment benchmarks was excerpted from TCEQ's Ecological Risk Assessment Guidance (TNRCC; RG-263, 2001 and the 2004 Draft Update)

# APPENDIX A: Derivation of the Ecological Screening Benchmarks

The benchmarks presented in this guidance are based on a consensus generally agreed upon by ecological workgroup members. During the selection process, the workgroup primarily sought agreement on selecting qualifying sets of benchmarks (e.g., Region 4 surface water screening values, ER-Ls from Long, et al., 1995), with the assumption that the whole set would be used rather than picking and choosing COCs individually from the various databases. However, in order to expand the list of COCs that have recommended benchmarks, individual values from other sources were also included. Preference for sets of benchmarks (or individual benchmarks) was based on the following characteristics:

- Those sets containing a large number of COCs;
- Those sets presenting a readily transparent development process;
- Those that were appropriate for conservative screening;
- Benchmarks used in other TNRCC programs, including regulatory criteria;
- Benchmarks used in other state and federal ERA programs;
- Those sets using data that include species relevant to Texas and the Gulf of Mexico, and
- Those sets that are relatively recent or meet current technical standards.

## Sediment Benchmarks

The benchmarks for sediment are intended to be protective of benthic biota, and are not necessarily protective of mammalian and avian receptors that may be exposed to COCs through the food chain or via the incidental ingestion of sediment. Although there are a variety of existing sources for sediment benchmarks, most are derived using one of two basic approaches. The first general category is the correlative or integrative approach which relies largely on paired field and laboratory data to relate the incidence of adverse biological effects to the dry-weight sediment concentration of a COC. The toxicity values are derived through a number of approaches including toxicity tests of spiked sediment and field sediment, equilibrium partitioning (EqP), apparent effects threshold (AET), and benthic community surveys. Since these types of benchmarks rely in part on the total concentration of COCs in sediment as a basis for development, the resultant screening values may have no relationship with the actual toxicity

of individual COCs in a mixture, or the ability of the COCs to bioaccumulate in aquatic or terrestrial organisms.  The second approach (e.g. EqP) is theoretically based, and relies on the physical/chemical properties of sediment and COCs to predict the level of contamination that would not cause an adverse effect on aquatic life.  In selection of the preferred sediment benchmarks specified in this guidance, the TCEQ and the ecological  workgroup relied primarily on references that used the correlative approach, although EqP-based benchmarks were developed for VOCs.

## Preferred Sediment Screening Benchmarks

The preferred benchmarks are provided in Table 3-3. The following sections discuss the sediment benchmark approaches that were evaluated, including those that were not chosen as preferred benchmarks.  This discussion does not attempt to cover every possible sediment screening benchmark or method.  These and other methodologies are discussed elsewhere (e.g. MacDonald, 1994; Neff, 1986; U.S. EPA, 1992; and Ingersoll, et al., 1997).  Alternate sediment benchmarks, including those discussed in this guidance, may be used with appropriate justification.  The use of alternate benchmarks is discussed in Section 3.5.1.

## Freshwater Sediment Benchmarks

For freshwater benchmarks, the primary benchmarks selected were the Threshold Effect Concentrations (TECs) from MacDonald et al. (2000).  Other sources include the Effects Range-Low (ER-L) values in Long and Morgan (1990), Lowest Effects Levels (LELs) from Persaud, et al. (1993), and the Interim Sediment Quality Guidelines (ISQG) from Environment Canada (1997).  The values in Jones, et al. (1997) derived using the EqP approach were evaluated, but were not included in the listing of preferred benchmarks.  However, EqP benchmarks were developed for VOCs by the ecological workgroup using TCEQ's $LC_{50}$ database and the modified approach suggested by Fuchsman (2003).  All of these approaches are discussed below.

### MacDonald et al. Threshold Effect Concentrations (TEC)

MacDonald et al. (2000) has developed sediment guidelines for 29 COCs in freshwater sediments.  Two values were developed - a threshold effect concentration (TEC), and a probable effect concentration (PEC).  The TEC represents a sediment concentration below which adverse effects are not expected to occur, and the PEC represents a concentration above which adverse effects are expected to occur more often than not.  Published sediment quality guidelines were compiled and divided into two categories depending on their original intent.  Where three or more acceptable sediment guidelines were available for a COC, TECs and PECs were calculated by determining the geometric mean of the previously published sediment guidelines.  The predictive ability of the TECs were evaluated using matching sediment toxicity and chemistry

data from field studies. Concentrations in sediment were compared to the corresponding TEC for that COC and samples were predicted to be not toxic if the measured concentrations were lower than the corresponding TEC. The TEC was considered reliable if more than 75% of the sediment samples were correctly predicted to be not toxic. The authors concluded that most of the TECs (21 of 28) provide an accurate basis for predicting the absence of sediment toxicity. This included 4 trace metals, 8 individual PAHs, total PAHs, total PCBs, and 7 organochlorine pesticides.

### Long and Morgan ER-Ls

This approach was first presented by Long and Morgan (1990) as part of the NOAA informal guidelines to help evaluate sediment chemistry data collected in the National Status and Trends Program (NSTP). The authors assembled a large sediment database that included effects and no effects field and lab data, for freshwater, estuarine, and marine organisms. COC concentrations (dry-weight normalized) observed or predicted by these methods to be associated with biological effects were ranked using percentiles. The lower 10th percentile concentration for those sediment COC concentrations associated with biological effects was defined as the ER-L value. Values below the ER-L were considered to represent the no effects range. The 50th percentile concentration for the ranked sediment COC concentrations associated with biological effects was defined as the effects range median (ER-M). COC concentrations between the ER-L and the ER-M values were considered to represent the possible effects range, and those above the ER-M were considered to represent the probable effects range. The ER-L values for antimony and silver were the only benchmarks used from this reference since other similar approaches (Smith, et al., 1996a) have incorporated more recent data sets.

### Ontario Ministry of the Environment (OME) Lowest Effects Levels (LELs)

The OME derived sediment guidelines for evaluation of sediments throughout Ontario (Persaud, et al., 1993). They defined a LEL as a level of sediment contamination that can be tolerated by the majority of benthic organisms, and a severe effects level (SEL) as the level at which pronounced disturbance of the sediment-swelling community can be expected. These benchmarks were derived from matching sediment chemistry and benthic community data from various geographic areas. OME used the Screening Level Concentration (SLC) approach as developed by Neff et al. (1986). This is a two-step process where a individual species SLC is first calculated for each COC by plotting the frequency distribution of the COC concentrations over all sites (at least 10) where that particular species is present. The 90th percentile is then selected as the SLC for that species. Then 90th percentiles for all the species present are plotted and the 5th (the LEL) and 95th (the SEL) percentiles are calculated. Hence the 5th percentile SLC (the LEL) is the COC concentration above which 95% of the species SLCs are found (the highest level of a COC that can be tolerated by 95% of the benthic species). The adequacy of the SLC is directly related to the size of the database and its variability. An advantage to this

approach is that it is based on chronic population-level effects on indigenous biota and can be used for polar and ionic organics and metals as well as nonpolar organics. However it does not establish a direct cause and effect relationship between a single COC and benthic survival, and it requires a large amount of data including sediment analyses and benthic assessments. LELs for iron, manganese, several pesticides and individual Polychlorinated Biphenyl (PCB) aroclors were used as freshwater benchmarks in Table 3-3.

### Interim Sediment Quality Guidelines (ISQG) from Environment Canada

Environment Canada (1997), describes the derivation of the Canadian freshwater and marine sediment quality guidelines for dichlorodiphenyltrichloroethane (DDT) and its degradation products, dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyldichloroethane (DDD). This reference was used in the guidance as the source for marine sediment benchmarks for Sum DDT, Sum DDE, or Sum DDE. The terms Sum DDT, Sum DDE, or Sum DDE are used to represent the sum of the concentrations of the *p,p'* and *o,p'* isomers. The reference provides interim sediment quality guidelines for sum DDD, sum DDE, and sum DDT for the protection of marine and estuarine life. Interim sediment quality guidelines for sum DDD and sum DDE for the protection freshwater aquatic life, and a provisional value for sum DDT for freshwater aquatic life are also provided but were not used. These values were developed in accordance with the procedures established by the CCME 1995 which relies on the NSTP approach (Long and Morgan, 1990) (with modifications) and the spiked-sediment toxicity test (SSTT) approach in combination. If insufficient information is available to derive interim guidelines, Canada uses other approaches or guidelines that may be adapted as a provisional ISQG. Modifications of the NSTP approach include the separate evaluation of information for freshwater and marine systems, an expanded data set, and use of derivation procedures that consider all compiled information (effect and no-effect data). All values are TELs with the exception of that for Sum DDE for freshwater sediments since the minimum data requirements (at least 20 entries in both the no-effect and effects data sets) were not met. Based on available data, Canada determined that freshwater and marine crustaceans are affected at similar concentrations of sum DDT, and they elected to use the marine ISQG as a provisional freshwater sediment value.

### Equilibrium Partitioning (EqP) Approach

The TCEQ evaluated the use of this approach to expand the list of freshwater sediment benchmarks for organic COCs. The Oak Ridge National Laboratory (Jones et al., 1997) has used this approach to calculate benchmarks for 75 nonionic organic COCs. Although this database was not used, the ecological workgroup did use a modified EqP approach (Fuchsman, 2003) to develop freshwater and marine sediment benchmarks for 57 volatile COCs. EqP remains an alternative method for developing sediment benchmarks (and PCLs) provided there is adequate justification (see the EqP discussions in Sections 3.5.1.2, 3.13.2, and 6.3).

## Marine Sediment Benchmarks

For marine benchmarks, the primary benchmarks selected were the ER-L values in Long et al. (1995). Other sources include the TELs from Smith, et al. (1996b), the ISQG from Environment Canada (1997), and the EqP-derived benchmarks for volatiles developed by the ecological workgroup. The Apparent Effects Threshold approach and the Florida TEL approach were evaluated, but were not used as preferred benchmarks. These approaches are discussed below (with the exception of Canada's ISQGs and the EqP benchmarks which have been previously discussed).

### Long, et al., 1995 ER-Ls

Long, et al. (1995) established Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values from an updated version of the BEDS database developed by Long and Morgan (1990). Here, freshwater data was omitted, and new data was added. Like Long and Morgan (1990), studies included chemistry data and bioassays of field samples, toxicity tests using spikes of clean sediments, benthic community analyses, and equilibrium-partitioning modeling. No-effects data were separated from data where an effect was observed; then the effects data were sorted by increasing concentrations of each COC. For each COC, the ER-Ls and ER-Ms were defined as in Long and Morgan (1990).

Using amphipod survival bioassasys, O'Connor, et al. (1998) used the EPA Environmental Monitoring and Assessment Program - Estuaries (EMAP-E) and the NOAA Status and Trends Bioeffects Surveys to test the applicability of various sediment toxicity guidelines. Of the 481 samples without an ER-L exceedance, only 5% were determined to be toxic. The authors concluded that this was a good indication that toxic effects are unlikely at concentrations below an ER-L. Similarly, Long et al., 1998 found that the percentages of false negatives (toxic response) for ER-Ls and TELs were 11 and 9% respectively when synoptically collected chemistry and amphipod toxicity test data for 1,068 samples from studies compiled by EPA and NOAA during 1990 to 1993 were evaluated. The ER-L values for metals, PAHs, total DDTs, and total PCBs were the marine benchmarks used from this reference. The ER-L values have been widely used as screening tools in ecological risk assessments.

### Canadian Sediment Quality Guideline (TELs) for Marine Waters

Smith, et al. (1996b) used CCME protocols (CCME, 1995) for the derivation of environmental quality guidelines. A modified version of the NSTP approach was used (Long and Morgan, 1990) and the NOAA BEDS database was used. The data for the effects data set and the no-effects data set were sorted for each COC and arranged in ascending order of COC concentrations. A TEL was calculated to be the geometric mean of the lower 15th percentile concentration of the effects data set, and the 50th percentile concentration of the no-effects data

set. The TEL was intended to estimate the concentration for a given COC below which adverse biological affects only rarely occurred. The PEL was calculated to be the geometric mean of the 50th percentile concentration of the effects data set, and the 85th percentile of the no-effects data set. The PEL was intended to represent the concentration for a given COC above which adverse biological affects frequently occurred. TELs are draft interim sediment guidelines in the absence of adequate spiked-sediment toxicity test data. The marine TELs for chlordane, lindane, dieldrin and phthalates were used for this guidance.

### Apparent Effects Thresholds (AET)

This methodology was first developed by Barrick et al. (1988) using empirical data from Puget Sound, Washington. The AET is the sediment concentration of a COC above which statistically significant ($p \le 0.05$) biological effects are always expected. The AET values are empirically derived from paired (field and laboratory) sediment chemistry and biological effects measures such as sediment toxicity tests or benthic community surveys. The significance of adverse effects is assessed by statistical comparisons with suitable reference or control sediments. For a given data set, the AET value for a particular COC is the sediment concentration above which a particular adverse biological effect has always been found to be statistically significant, relative to a reference condition. Use of these values for a specific location or region elsewhere may be overprotective or under protective. The AET approach requires a large data base of COC data with at least one biological indicator. Unless site-specific data is used to derive an AET, the other benchmarks discussed in this guidance are presumed to be more appropriate in a Tier 2 ERA since the AET represents the sediment concentration above which statistically significant biological effects are always expected and therefore presents a substantial risk of under protection.

### Florida Department of Environmental Protection TELs

The Florida Department of Environmental Protection used a similar weight-of-evidence approach to develop sediment quality guidelines for Florida coastal waters (MacDonald, 1994 and MacDonald et al., 1996). These guidelines were based on empirical analyses of data compiled from numerous field and laboratory studies performed for estuaries and bays throughout North America. As the Long et al. (1995) data set was used, only marine and estuarine data is included. Data was added, particularly for Florida and southeast Gulf of Mexico. Data for COCs in Florida were retrieved and sorted in ascending COC concentration order. The data was sorted into an effects data set, and an no-effects data set, and a TEL and PEL were calculated for each constituent. This reference was not used since the TELs were essentially equivalent to those used by Smith et al. (1996b).

**Other Marine Sediment Quality Guidelines for PAHs**

In addition to PAH benchmarks proposed for individual and combined PAHs in this guidance, other methods have been proposed. Swartz, et al. (1995) proposed the $\sum$PAH model which predicts the probability of acute toxicity of PAH contaminated marine sediments using a combination of EqP, Quantitative Structure Activity Relationships (QSAR), toxic unit, additivity, and concentration-response models. Assuming that the toxic effects of PAHs are additive, the total number of toxic units of thirteen PAH compounds were used to predict the probability of toxicity to amphipods using a concentration-response model derived from spiked sediment toxicity tests. With inputs of $f_{oc}$ and bulk concentrations of PAHs in sediment, the model predicts the probability that a sediment sample will be acutely toxic to amphipods (mortality >24%), not toxic (mortality <13%), or cause uncertain toxicity (mortality 13 to 24%).

The authors concluded that the model accurately predicts toxicity of PAH-contaminated sediments when PAHs are the principal COCs and the 13 PAHs used in the model development are the dominant PAHs. In another paper, (Swartz, 1999) discusses the "mixture paradox" for PAHs in that sediment quality guidelines derived from experimental determination of toxicological effects of individual PAHs (spiked-sediment tests) will greatly underestimate ecological effects in the field that are associated with the guideline but actually caused by the PAH mixture, whereas guidelines derived from the correlation of ecological effects with the concentration of an individual PAH in field-collected sediment will greatly overestimate the effects actually caused by the single compound. For this reason, the author believes that guidelines for individual PAHS are inappropriate. With PAH concentrations normalized for organic carbon, the author proposes guidelines for threshold (TEC) - 290 ug/g organic carbon (OC), median (MEC) 1,800 ug/g OC, and extreme (EEC) 10,000 ug/g OC effects concentrations as a mixture of total PAHs (TPAHs) in marine or estuarine sediments. The author concludes that the TEC is the most useful guideline because mixtures of PAHs are unlikely to cause adverse effects on benthic ecosystems below the TEC, and that the TPAH guidelines agree with others (EqP, $\sum$ PAH toxicity threshold, ER-L and SLC) within a factor of two.

**Using Sediment Benchmarks to Derive PCLs for Benthic Communities**

As detailed in Section 3.1.3.2 related to the selection of comparative and final PCLs, one approach to developing a PCL protective of the benthic invertebrate community employs the same databases used to derive the sediment screening benchmarks. The benchmarks listed in Table 3-3 were based on conservative primary effect levels such as the Effects Range-Low (ER-L) from Long and Morgan (1990), and the Threshold Effect Concentrations (TECs) from MacDonald et al. (2000). For each of these values, there is a corresponding higher value that represents a second level of effects such as the Effects Range-Median (ER-M) from Long and Morgan (1990), and the Probable Effect Concentrations from MacDonald et al. (2000). These second effect levels appear in Table A-2. As indicated in Section 3.13.2, the person may view the primary effect levels as NOAELs and the second effect levels as LOAELs. In developing the

benthic PCL, the same logic presented in the guidelines in Section 3.13.2 pertaining to NOAELs/LOAELs should be applied, with the understanding that the midpoint value may be proposed as the PCL but it is not a default (i.e., if sufficient evidence suggests that the midpoint is not protective, then this value will be questioned). Also, when using Tables 3-3 and A-2 to develop a sediment PCL for a volatile COC that was derived from the EqP approach, the person should remember that even though the surface water benchmarks and TCEQ's $LC_{50}$ database were used as input, the resulting values are not effects-based for benthics and therefore it may be prudent to be conservative (i.e.,proposing a PCL that is less than the midpoint). This is particularly true when the acute surface water input number used to derive the second effects level was developed from equations in DiToro et al. (2000) as shown in the example box below. These values appear in Table A-2 with a "o" footnote. Alternatively, the person could use the acute-to-chronic ratio of 5.09 suggested in DiToro et al. (2000) and input a chronic surface water number into the sediment benchmark equation. In this case, the midpoint between the resulting values and the corresponding primary effect levels in Table 3-3 would be an acceptable PCL.

**EXAMPLE CALCULATION OF ACUTE SURFACE WATER BENCHMARKS USING THE DITORO ET AL. METHOD**

Step 1: DiToro et al., 2000, Equation 37 without the acute-to-chronic ratio (ACR):

Log (WQB  mmol/L) = Log (35.3) + $C_1$ −0.945 x Log($K_{ow}$)

Step 2: Units Conversion mmol/L to mg/L

WQB (mg/L) = WQB (mmol/L) x MW

Where:

WQB = acute water quality benchmark in surface water
$C_1$ = chemical class correction (0 for aliphatic COCs, -0.244 for halogenated chemicals)
$K_{ow}$ = octonal water partition coefficient (unitless)
MW = molecular weight (g/mol)


Example Calculation: Benzene (Log Kow = 1.99, MW = 78.1 g/mol)

Log (WQB) = Log (35.3) + 0 – 0.945 x 1.99
Log (WQB) = 1.55 – 1.88
Log (WQB) = -0.33
WQB = 0.47 mmol/L x 78.1 g/mol
WQB = 36.1 mg/L for Benzene

A chronic WQB  can be obtained by dividing by the ACR of 5.09:        36.1 mg/L ÷ 5.09 = 7.09 mg/L


Example Calculation: Carbon Tetrachloride (Log Kow = 2.44 MW = 154 g/mol)

Log (WQB) = Log (35.3) –0.244 – 0.945 x 2.44
Log (WQB) = 1.55 – 0.244 – 2.31
Log (WQB) = -1.00
WQB = 0.100 mmol/L x 154 g/mol
WQB = 15.2 mg/L for Carbon Tetrachloride

A chronic WQB can be obtained by dividing by the ACR of 5.09:       15.2 mg/L ÷ 5.09 = 2.99 mg/L

**Table A-2. Second Effects Levels for Sediment**

| CAS # | Constituent | Freshwater | Marine |
|-------|-------------|------------|--------|
| *Inorganics (mg/kg dry wt.)* | | | |
| 7440-36-0 | Antimony | 25[a] | |
| 7440-38-2 | Arsenic | 33 | 70 |
| 7440-43-9 | Cadmium | 4.98 | 9.6 |
| 7440-47-3 | Chromium | 111 | 370 |
| 7440-50-8 | Copper | 149 | 270 |
| 7439-89-6 | Iron | 40,000[b] | |
| 7439-92-1 | Lead | 128 | 218 |
| 7439-96-5 | Manganese | 1,100[b] | |
| 7439-97-6 | Mercury | 1.06 | 0.71 |
| 7440-02-0 | Nickel | 48.6 | 51.6 |
| 7440-22-4 | Silver | 2.2[a] | 3.7 |
| 7440-66-6 | Zinc | 459 | 410 |
| *Polycyclic Aromatic Hydrocarbons (mg/kg dry wt.)* | | | |
| 83-32-9 | Acenaphthene | 0.089 | 0.500 |
| 208-96-8 | Acenaphthylene | 0.130 | 0.640 |
| 120-12-7 | Anthracene | 0.845 | 1.1 |
| 56-55-3 | Benz(a)anthracene | 1.05 | 1.6 |
| 50-32-8 | Benzo(a)pyrene | 1.45 | 1.6 |
| 218-01-9 | Chrysene | 1.29 | 2.8 |
| 53-70-3 | Dibenz(a,h)anthracene | 0.140[k] | 0.260 |
| 206-44-0 | Fluoranthene | 2.23 | 5.1 |
| 86-73-7 | Fluorene | 0.536 | 0.540 |
| 91-57-6 | 2- Methyl naphthalene | | 0.670 |
| 91-20-3 | Naphthalene | 0.561 | 2.1 |
| 85-01-8 | Phenanthrene | 1.17 | 1.5 |
| 129-00-0 | Pyrene | 1.52 | 2.6 |
| | Low Molecular Weight PAHs | | 3.16[e] |
| | High Molecular Weight PAHs | | 9.6[f] |
| | Total PAH | 22.8[g,j,k] | 44.79[g,j] |
| *Chlorinated Pesticides/PCBs/Benzenes (mg/kg dry wt.)* | | | |
| 309-00-2 | Aldrin | 0.08[b,i] | |
| 27323-18-8 | Aroclor 1254 | 0.34[b,i] | |
| 12674-11-2 | Aroclor 1016 | 0.53[b,i] | |

**Table A-2. Second Effects Levels for Sediment**

| CAS # | Constituent | Freshwater | Marine |
|-------|-------------|-----------|--------|
| 11096-82-5 | Aroclor 1260 | 0.24[b, i] | |
| 12672-29-6 | Aroclor 1248 | 1.5[b, i] | |
| 319-84-6 | alpha-BHC | 0.1[b, i] | |
| 319-85-7 | beta-BHC | 0.21[b, i] | |
| 58-89-9 | gamma-BHC (Lindane) | 0.00499 | 0.00099[d] |
| 608-73-1 | BHC | 0.12[b, i] | |
| 57-74-9 | Chlordane (Total) | 0.0176 | 0.00479[d] |
| 60-57-1 | Dieldrin | 0.0618 | 0.00430[d] |
| -72-20-8 | Endrin | 0.207 | |
| 118-74-1 | HCB (Hexachlorobenzene) | 0.24[b] | |
| 87-68-3 | HCBD (Hexachlorobutadiene) | 0.55[m] | |
| 1024-57-3 | Heptachlor epoxide | 0.016 | |
| 2385-85-5 | Mirex | 1.3[b] | |
| 72-55-9 | Sum DDE | 0.0313 | 0.374[d] |
| 72-54-8 | Sum DDD | 0.028 | 0.00781[d] |
| 50-29-3 | Sum DDT | 0.0629 | 0.00477[d] |
| | Total DDT | 0.572[i] | 0.046[i] |
| 1336-36-3 | Total PCBs | 0.676[i] | 0.180[i] |
| *Other Pesticides (mg/kg/dry wt.)* | | | |
| 8001-35-2 | Toxaphene | 0.032[m] | |
| *Phthalates (mg/kg dry wt.)* | | | |
| 117-81-7 | Bis(2-ethyl-hexyl)phthalate | | 2.647[d] |
| | Di-n-butyl phthalate | 0.043[l] | |
| *Volatiles (mg/kg dry wt.)*[n] | | | |
| 67-64-1 | Acetone | 360.18 | 1003.36 |
| 107-13-1 | Acrylonitrile | 1.36 | 1.04 |
| 71-43-2 | Benzene [o] | 45.01 | 45.01 |
| 104-51-8 | N-butylbenzene | 6.57 | |
| 103-65-1 | Propyl benzene | 4.35 | |
| 135-98-8 | Sec-butylbenzene | 5.28 | |
| 98-06-6 | Tert-butylbenzene | 7.26 | |
| 75-27-4 | Bromodichloromethane | 14.74 | |
| 78-93-3 | 2-butanone | 154.26 | |
| 75-15-0 | Carbon disulfide | 0.78 | |

**Table A-2. Second Effects Levels for Sediment**

| CAS # | Constituent | Freshwater | Marine |
|---|---|---|---|
| 56-23-5 | Carbon tetrachloride [0] | 37.33 | 37.33 |
| 108-90-7 | Chlorobenzene [0] | 19.87 | 19.87 |
| 124-48-1 | Chlorodibromomethane | 0.94 | |
| 67-66-3 | Chloroform (trichloromethane) | 5.63 | 25.8 |
| 74-87-3 | Chloromethane | 106.8 | 52.43 |
| 98-82-8 | Cumen | 53.95 | |
| 99-87-6 | p-Cymene | 5.98 | |
| 95-50-1 | 1,2-dichlorobenzene | 4.95 | 4.44 |
| 541-73-1 | 1,3-dichlorobenzene | 0.35 | 1.95 |
| 106-46-7 | 1,4-dichlorobenzene | 4.65 | 4.21 |
| 75-71-8 | Dichlorodifluoromethane | 22.09 | |
| 75-34-3 | 1,1-dichloroethane | 13.89 | |
| 107-06-2 | 1,2-dichloroethane | 28.69 | 25.80 |
| 75-35-4 | 1,1-dichloroethene | 11.22 | 92.47 |
| 156-60-5 | 1,2-dichloroethene (trans) | 71.84 | |
| 78-87-5 | 1,2-dichloropropane | 13.17 | |
| 542-75-6 | 1,3-dichloropropene | 1.37 | 0.26 |
| 100-41-4 | Ethylbenzene | 17.18 | 3.93 |
| 87-68-3 | Hexachlorobutadiene [0] | 12.76 | 12.76 |
| 67-72-1 | Hexachloroethane [0] | 13.77 | 13.77 |
| 110-54-3 | Hexane, n- [0] | 12.77 | |
| 591-78-6 | 2-hexanone | 28.20 | |
| 108-10-1 | 4-methyl-2-pentanone (MIBK) | 116.59 | 272.06 |
| 74-83-9 | Methyl bromide | 0.46 | 2.49 |
| 22967-92-6 | Methyl Mercury | N/A | |
| 80-62-6 | Methyl methacrylate | 56.98 | |
| 75-09-2 | Methylene chloride | 46.52 | 22.91 |
| 98-95-3 | Nitrobenzene [0] | 161.06 | 161.06 |
| 71-41-0 | 1-Pentanol [0] | N/A | |
| 67-63-0 | 2-Propanol [0] | 443.99 | |
| 100-42-5 | Styrene | 61.42 | 22.31 |
| 79-34-5 | 1,1,2,2-tetrachloroethane | 3.80 | 3.69 |
| 127-18-4 | Tetrachloroethene | 10.05 | 18.59 |
| 108-88-3 | Toluene | 17.29 | 5.66 |

**Table A-2.  Second Effects Levels for Sediment**

| CAS # | Constituent | Freshwater | Marine |
|---|---|---|---|
| 75-25-2 | Bromoform | 1.31 | 10.67 |
| 120-82-1 | 1,2,4-trichlorobenzene | 5.31 | 2.32 |
| 71-55-6 | 1,1,1-trichloroethane | 24.80 | 15.83 |
| 79-00-5 | 1,1,2-trichloroethane | 5.88 | 1.80 |
| 79-01-6 | Trichloroethene | 5.07 | 8.82 |
| 75-69-4 | Trichlorofloromethane | 10.12 | |
| 76-13-1 | 1,1,2-trichlorotrifluoroethane | 16.70 | |
| 95-63-6 | 1,2,4-trimethylbenzene | 4.58 | 12.95 |
| 108-67-8 | 1,3,5-trimethylbenzene | 4.59 | |
| 108-05-4 | Vinyl acetate [0] | 366.29 | |
| 75-01-4 | Vinyl chloride | 11.78 | |
| 108-38-3 | m-Xylene [0] | 2.08 | |
| 1330-20-7 | Xylenes | 12.01 | 7.47 |

Freshwater -  Unless otherwise noted, values are Threshold Effect Concentration (TEC) from: MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems.  Arch. Environ. Contam. Toxicol. 39:20-31.

Marine -  Unless otherwise noted, values are Effects Range Median (ERM) from: Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environ. Manage. 19(1):81-97.

a  Effects Range Median (ERM) from: Long, E.R. and L.G. Morgan. 1990.  The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52, March 1990.

b  Severe Effects Level (SEL) from: Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Water Resources Branch. Ontario Ministry of the Environment and Energy.  August.

c  Probable Effect Levels (PEL) from: Environment Canada.  1997.  Canadian Sediment Quality Guidelines for DDTs. Environment Canada, Guidelines and Standards Division. January, 1998 Draft.

d  Probable Effect Level (PEL) from: Smith, S.L., D.D. MacDonald, K.A. Keenleyside, and C.L. Gaudet. 1996b. The Development and Implementation of Canadian Sediment Quality Guidelines.

**Table A-2.  Second Effects Levels for Sediment**

In: Development and Progress in Sediment Quality Assessment: Rationale, Challenges, Techniques & Strategies. Ecovision World Monograph Series. Munawar & Dave (Eds.). Academic Publishing, Amsterdam, The Netherlands.

e       The sum of the concentrations of the following compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methyl napthalene.

f       The sum of the concentrations of the following compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, and dibenzo [a,h]anthracene.

g       The sum of the concentrations of each of low and high molecular weight PAHs listed above and any other PAH compounds that are COCs.

h       Values in the original reference were based on percent total organic carbon. These values were converted to bulk sediment values by assuming 1% TOC (SEL x 0.01).

i       When benchmarks represent the sum of individual compounds, isomers, or groups of congeners, and the chemical analysis indicates an undetected value, the proxy value specified at §350.51 (n) shall be used for calculating the sum of the respective compounds, isomers, or congeners.  This assumes that the particular COC has not been eliminated in accordance with the criteria at §350.71 (k).

j       The benchmarks for total PAHs are the most relevant in evaluating risk in an ERA as PAHs almost always occur as  mixtures.  Values for individual, low molecular weight, and high molecular weight PAHs are provided as guidelines to aid in the determination of disproportionate concentrations within the mixture that may be masked by the total.  See discussion in Section 3.5.4.

k       CCME (Canadian Council of Ministers of the Environment).  1999.  Canadian environmental quality guidelines.  Winnipeg, Manitoba.

l       Cubbage, J., D. Batts, and S. Briedenbach.  1997.  Creation and analysis of freshwater sediment quality values in Washington State.  Environmental Investigations and Laboratory Services Program.  Washington Department of Ecology.  Olympia, Washington.

m       NYSDEC (New York State Department of Environmental Conservation).  1999.  Technical guidance for screening contaminated sediments.  Division of Fish , Wildlife, and Marine Resources.  Albany, New York.  36 pp.

n       Benchmarks derived using formula in: Fuchsman, P.C. 2003. Modification of the Equilibrium Partitioning Approach for Volatile Organic Compounds in Sediment.  Environ Toxicol Chem. 22:1532-1534.  TCEQ's LC50 database used for water quality values, except where noted.  TRRP-24 default values of 1% fraction organic carbon ($f_{oc}$) and 0.37 porosity were used.  The person should adjust these values if sufficient site-specific data indicate they are not representative.

o       Acute water quality benchmarks were used as input for these COCs and were derived from DiToro, D.M., J.A. McGrath, and D.J. Hansen.  2000.  Technical basis for narcotic chemicals and polycyclic aromatic hydrocarbon criteria.  I. Water and tissue. Environ. Toxicol. Chem. 19: pp 1951-1970.

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